Effect of Fe and Si on Structure and Mechanical Properties of Complex-Alloyed AL-Zn-Mg-Cu Alloys Produced by P/M and Casting Techniques

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In order to clear the possibility of using recycled aluminum that usually has an increased content of Fe and Si, structure and mechanical properties of high-strength Al-Zn-Mg-Cu alloys additionally alloyed with only Fe and Si, and of Al-Zn-Mg-Cu alloys additionally alloyed with Mn, Zr, Sc, Fe and Si were studied. Tensile mechanical properties were determined for extruded rods after T6 treatment (quenching and artificial aging). Rods were manufactured from ingots cast into water-cooled copper molds as well as by P/M technique with using powders atomized from the melt by high-pressure water. Structure and distribution of alloying elements were studied for alloys in starting condition, after extrusion and T6 treatment by OM, SEM and TEM techniques. The SEM apparatus had a device for X-ray microspectral analysis.

The structure of Al-Zn-Mg-Cu ingot was of a dendrite character. Zr and Sc additions led to the formation in ingots of a grain structure with the grain size of 15-25 μm. Primary particles of $Al_3(Sc_{1-x}Zr_x)$ intermetallic were observed inside of grains, and a presumable precipitation of Zn, Mg, and Cu in grain boundaries was revealed. In grain boundaries of ingots alloyed with Fe the eutectic (Al+ $FeAl_3$) was found. In rods manufactured from ingots after T6 treatment SEM investigation detected the existence of rather coarse intermetallics containing Fe that has led to some lowering the plasticity together with increasing the strength.

As distinct from cast alloys, in powders of Al-Zn-Mg-Cu alloys with Fe and Si additions a uniform distribution of all elements in powder body was observed. However, in T6 treated rods of alloys with Si additions precipitates of Mg_2Si type were registered by SEM technique. TEM investigation of T6 treated rods of both P/M and cast alloys revealed a large amount of hardening η′-particles as well as of secondary coherent $Al_3(Sc_{1-x}Zr_x)$ particles of several nm in size.

A rod from the cast alloy Al-9Zn-3Mg-2.3Cu with additions of Mn, Zr, Sc due to its non-recrystallized structure in T6 condition had a high level of strength ($\sigma_{0.2}$ = 696 MPa, σ_U = 789 MPa) with the plasticity δ = 12.3 %. Without alloying with Sc the non-recrystallized structure in rods of cast alloys is not retained. Introducing 0.3–1.0 wt. % Fe to the alloy caused some increase of the yield stress ($\sigma_{0.2}$ = 746 MPa) with preserving a satisfactory plasticity δ = 6-9 %.

As distinct from the rod of cast alloy, the P/M rod Al-9Zn-3Mg-1.2Cu had a high level of strength characteristics ($\sigma_{0.2}$ = 640 MPa, σ_U = 700 MPa) with δ = 6 % without Sc addition due to retaining the non-recrystallized structure by P/M technique. The additions of Fe in the amount of 0.3-1.0 wt. % to this alloy have also increased the strength ($\sigma_{0.2}$ = 660-690 MPa, σ_U = 710-750 MPa) with δ = 6-9 %. Introducing to 0.3 wt. % Si into the baseline P/M alloy has not lowered its mechanical properties. At larger Si content the strength lowered, and the plasticity grew. Thus, the rod of the alloy with about 1 wt. % Si had $\sigma_{0.2}$ = 400 MPa, σ_U = 500 MPa and δ = 14 %.

P/M alloys that contained Fe and Si together (each of them to 1 wt. %) had also a rather high level of mechanical properties. In the rod of the alloy with 1 wt. % Si and 1 wt.% Fe the following values were obtained: $\sigma_{0.2}$ = 531 MPa, σ_U = 602 MPa, δ = 9-10 %.